IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of applications to the **WAIKATO DISTRICT COUNCIL** and **WAIKATO REGIONAL COUNCIL** by **WEL NETWORKS LTD** for resource consents to authorise the establishment, operation and maintenance of 28 wind turbines for the generation of electricity and associated activities on the Wharauroa Plateau near Te Uku

STATEMENT OF EVIDENCE OF DUNCAN MCMILLAN

1. INTRODUCTION

Qualifications and experience

1.1 My name is Duncan McMillan. I am a contract mechanical engineer currently working as a Project Manager/Project Engineer at New Zealand Steel. I am also a director of Gusto Energy Ltd, manufacturer of small wind turbines and supplier of renewable energy equipment.

1.2 My qualifications are Bachelor of Engineering (Mechanical, 1981) and Master of Engineering (1991), both from the University of Auckland. My post-graduate degree had a major focus on experimental fluid dynamics, aerodynamics and wind engineering.

1.3 I have significant experience in wind tunnel testing (primarily for Uniservices, at the University of Auckland), in product development (products with a fluid dynamic operating principle) and in project management/engineering in heavy industry, including the electricity sector (thermal power stations).

1.4 In the position of Technical Manager – Micropower, I was employed by Vortec Energy Ltd in 2000, who was engaged in the development of a new concept in wind turbines. This involved extensive prototype design and build work, followed by thorough field testing and trials to provide proof of concept.

1.5 My own company, Gusto Energy Ltd, has developed a 2 kW horizontal axis wind turbine and sells the product in NZ and overseas. The machines were fully designed, manufactured and marketed by Gusto Energy Ltd. Development of the wind turbine encompassed many facets of engineering including aerodynamics, wind engineering and performance verification.

Involvement in project

1.6 I was invited by Dr David Russell Black to peer review his statement of evidence (dated November 2007) regarding the possible health and safety concerns surrounding the construction and operation of 28 wind turbines for the generation of electricity on the Wharauroa Plateau near Te Uku. I was also provided with the submissions presented by Mr S.B.Cox on the same subject, which allege that Dr Black's evidence represents a misunderstanding of the mechanics and aerodynamics of wind turbines. I have reviewed these documents along with several others, taking particular interest in those parts relating to the operational principles, aerodynamics and wind engineering of wind turbines.

Purpose and scope of evidence

1.7 Against that background, the purpose of my evidence is to comment on Dr Black's understanding of the mechanics and aerodynamics of wind turbines, and energy generation as reflected in the evidence given by him before the Committee in November last year.

1.8 In that regard, my evidence will address the following matters:

(a) The principle of wind energy (section 3);

(b) Laminar and turbulent flow (section 4); and

(c) Aerodynamic principles and noise issues (section 5).

Expert Witness Code of Conduct

1.9 I have been provided with a copy of the Code of Conduct for Expert Witnesses contained in the Environment Court's Consolidated Practice Note 2006 [2006] NZRMA 357. I have read and agree to comply with that code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

2. SUMMARY

2.1 Dr Black's evidence discusses concepts regarding the mechanics and aerodynamics of wind turbines in order to provide a basis for his discussion of health effects. Although in some cases the use of specific terms or phrases could be more appropriate, the intent and overall meaning of Dr Black's evidence is not misleading and in general satisfactorily conveys the concepts under discussion.

2.2 Some readers with specialist backgrounds may notice the mis-use of some terms but the wider audience would get a reasonable representation of what actually happens.

2.3 I have no doubt that Dr Black's intentions are to convey the concepts he addresses in the most genuine way and what may be conceived as erroneous detail by some individuals does not in any way impact on the conclusions Dr Black draws with regards to public health.

3. THE PRINCIPLE OF WIND ENERGY

3.1 The principle of wind energy, described in a few sentences at paragraph 4.5 of Dr Black's evidence, is reasonably covered in this paragraph, beginning with the origins of wind which are:

(a) In solar energy, which heats the earth and causes atmospheric pressure variations; and

(b) In large-scale rotation of air masses due to the earth's rotation.

3.2 The rotor of a Horizontal Axis Wind Turbine (HAWT), typically with two or three blades, extracts the kinetic energy from the wind and delivers it to a generator. Active yaw systems ensure the wind turbine is always facing the wind, and many turbines have blade pitch change systems to control power absorbed by the wind.

3.3 To clarify the use of the term "synchronously" in the context of the last sentence of paragraph 4.5 of Dr Black's evidence, Dr Black is referring to the phase relationships of the turbine output voltages – all 28 turbines are in phase with each other and are all very close to national grid frequency of 50 Hz. Another use of the term "synchronous" with regards to grid-connected turbine generators is to describe the type of generator, as there are generally two types of AC rotating machines: synchronous and non-synchronous. Furthermore the term "synchronising" in relation to grid-connected generation equipment is commonly used to describe the

process by which the phase timing of the AC generating machine is matched to the grid before the machine is connected to the grid, or goes “on line”.

3.4 There is nothing incorrect in paragraph 4.5, although more appropriate wording to very briefly describe the principle of wind energy might be as in 3.1 above.

4. LAMINAR AND TURBULENT FLOW

4.1 Dr Black addresses laminar and turbulent flow in paragraphs 4.8, 4.9 and 5.2 of his evidence.

4.2 At paragraph 4.8, Dr Black describes how the upstream flow of air approaching a wind turbine is “relatively” laminar. While that description is not misleading, insofar as the flow is less turbulent upstream of the turbine than it is downstream, the use of the term “laminar” in this context should be avoided as it has a specific fluid dynamic definition and it may be omitted without the loss of any clarity or meaning to the points under consideration.

4.3 Laminar flow is steady and smooth. The velocity of air in laminar flow is constant, which means it does not change in magnitude or direction. Air flowing over ground has turbulence associated with it that is partly dependant on the ground roughness, so the approach flow to a wind turbine strictly speaking will not be laminar. Compared to the downstream flow however the approach flow is relatively steady and smooth. Turbulent flow is of an unsteady, agitated nature with random and erratic variations in velocity in all directions. Turbulence varies at least in scale and magnitude and for the context herein is quantified by the wind engineering term “Turbulence Intensity”.

4.4 Dr Black’s evidence creates an impression that turbulence levels of the wind will change due to the presence of a wind turbine and these changes will dissipate in the downstream flow, and in my view this is correct.

5. AERODYNAMIC OPERATING PRINCIPLE OF A WIND TURBINE, AND NOISE

5.1 Paragraph 4.9 of Dr Black’s evidence addresses two concepts, being the basic aerodynamic operating principle, and the generation of noise, which deserve a little expansion.

5.2 A wind turbine blade generates lift and drag, not unlike the wing of an aircraft or the sail of a yacht, insofar as a pressure difference between the two sides of the lifting surface (the wing or the sail) results in a force on that surface. In the case of a wind turbine blade the airflow is made up of two components, one due to the wind and

the other due to the rotation of the blade. The sum of these two components gives rise to a resultant velocity vector which varies in magnitude and direction over the length of the blade. Each blade element can therefore be analysed for its contribution to the overall forces on the blade. Forces perpendicular (at right angles to) the local flow direction (at each blade element) and parallel to it can be summed to yield a resultant force which can then be resolved into forces perpendicular to the plane of the wind turbine rotor and parallel to it. The sum of all these perpendicular forces on all blades is the thrust (in the along-wind direction). The sum of all the forces parallel to the plane of the wind turbine rotor for all blades is the torque (in the across-wind direction), and this total torque drives the generator.

5.3 The opening sentence of paragraph 4.9 in Dr Black's evidence is therefore not incorrect, but rather a simplification.

5.4 It is my understanding that noise of aerodynamic origin (as opposed to mechanical origin) is largely due to upstream turbulence levels and certain features of the blade geometry. Aerodynamic noise increases exponentially with the local blade element velocity, so most of it would be associated with the tip regions of the blades.

5.5 The reference to noise and its association with turbulence as described in paragraph 4.9 is not misleading although might better be described with different phrasing.

5.6 The use of the terms "laminar" and "turbulent" has already been discussed above.

6. MASS CONTINUITY AND PRESSURE VARIATIONS

6.1 The main concept being presented in paragraph 4.13 of Dr Black's evidence is that the moving mass of air that encounters a wind turbine is not degraded or adversely affected in any way. As pointed out in that paragraph, the principle of mass continuity applies, and since the air velocity downstream of the turbine reduces, the stream tube (boundary of the body of air which passes through the turbine's blades) diameter must increase to compensate. This is because, in a given time, the same volume of air that approaches a wind turbine must also leave it, albeit at a lower velocity. The "plug" of air leaving the turbine therefore has a shorter, wider cylindrical shape than the plug of air approaching it.

6.2 Paragraph 4.13 also touches on the subject of pressure loss downstream of the wind turbine rotor. This is further discussed in paragraph 4.14 and a lower pressure must exist immediately downstream of the turbine rotor because a rotating blade set has an along-wind thrust associated with it that equates to the product of an equivalent surface area and pressure differential.

6.3 Although there may be modern mathematical models for the flow of air around a wind turbine with high degrees of accuracy, simple mathematical modelling always makes certain assumptions about the physical characteristics of the air, like viscosity and density, which are quite different from the real world but nevertheless enable a better understanding of how pressures and velocities vary around a wind turbine. With an understanding of these simple models it is hard to imagine that any measurable pressure effects due to the presence of a wind turbine could be detected several kilometres downstream.

6.4 Paragraphs 4.13 and 4.14 therefore offer a reasonable explanation of these two concepts and I am in general agreement with the conclusions drawn therein.

Duncan McMillan
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